Technical Report A-94-6
September 1994

US Army Corps
of Engineers
Waterways Experiment
Station

Aquatic Plant Control Research Program

Biological Studies of *Bagous hydrillae*

by *Gary R. Buckingham, Joseph K. Balciunas*
U.S. Department of Agriculture

Approved For Public Release; Distribution Is Unlimited

Prepared for Headquarters, U.S. Army Corps of Engineers

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U.S. Department of Agriculture
Agricultural Research Service
Gainesville, FL 32614-7100

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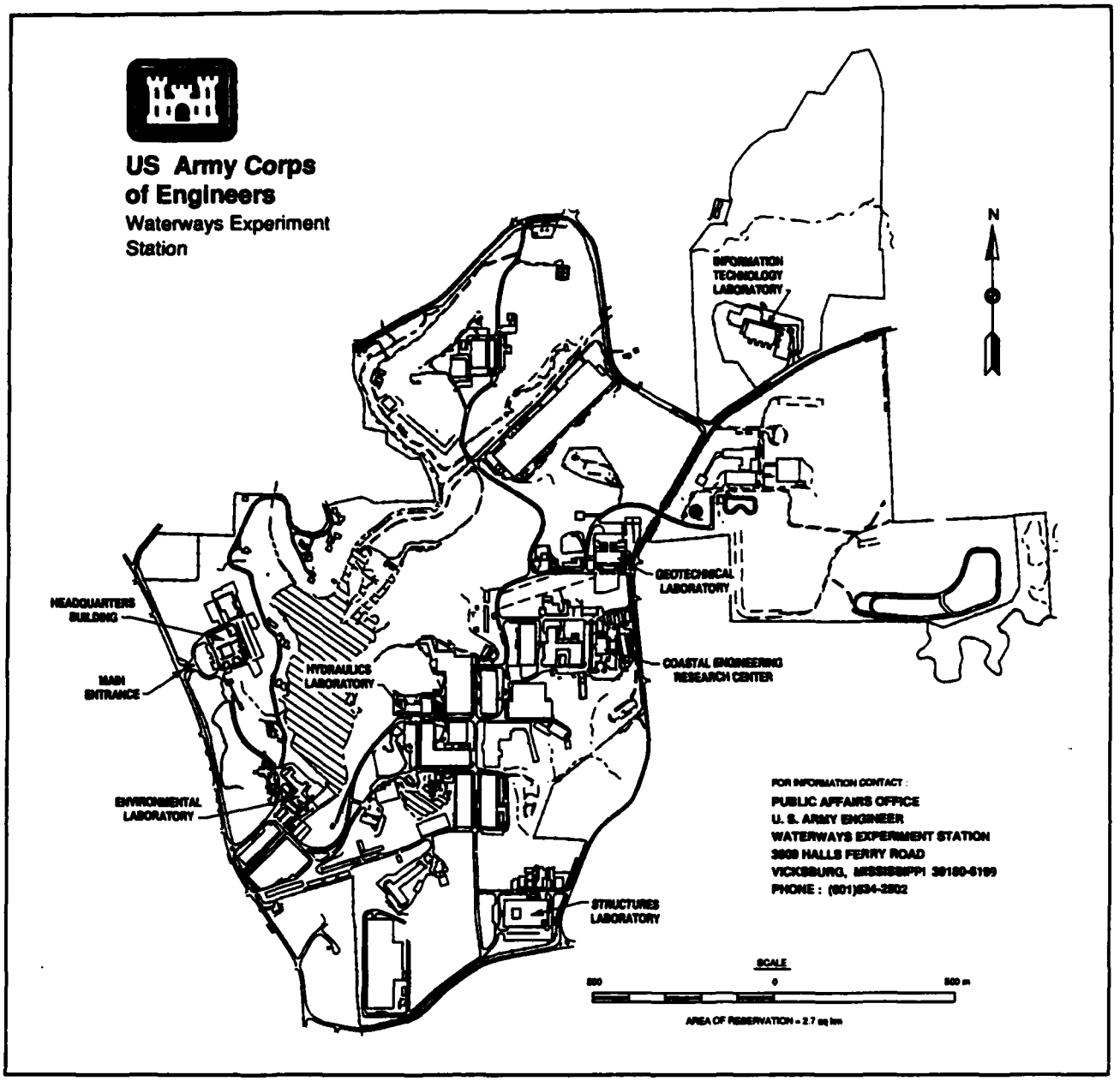

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Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 31799. The APCRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel, Jr., was Assistant Manager, ERRAP, for the APCRP. Technical Monitor during this study was Ms. Denise White, HQUSACE.

The Principal Investigators for this study were Drs. Gary R. Buckingham and Joseph K. Balciunas, U.S. Department of Agriculture - Agricultural Research Service (USDA-ARS). The USDA Coordinator for this project was Dr. Ted Center, USDA-ARS, Fort Lauderdale, FL.

The study was conducted under the direct supervision of Dr. Alfred F. Cofrancesco, Jr., Aquatic Ecology Branch (AEB), Ecological Research Division (ERD), EL, and Dr. Edwin A. Theriot, Chief, AEB, and under the general supervision of Dr. Conrad J. Kirby, Chief, ERD, and Dr. John W. Keeley, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Introduction

Background

Hydrilla, *Hydrilla verticillata* (L. f.) Royle, is an adventive submersed aquatic macrophyte that has become a major nuisance aquatic plant across the southern United States and in scattered Eastern locations north to Delaware. Recently, hydrilla populations have increased in the Tennessee Valley Authority waterways and have invaded lakes in the Sierra foothills of California. Hydrilla was listed as the top priority for biological control of nuisance aquatic plants in the report of the Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA) Research Planning Conference on Biological Control, March 20-22, 1984. It is or has been the subject of major research or control efforts by the ARS, the Corps of Engineers, the U.S. Environmental Protection Agency, the Bureau of Land Management, the USDA Animal Plant Health Inspection Service, the California Department of Agriculture, the University of Florida, and various other state and Federal organizations. Hydrilla has been an ARS biological control target nuisance aquatic plant for at least 17 years.

Bagous hydrillae is a small Australian weevil that extensively damages hydrilla in its native environment. Adults feed externally on submersed stems and leaves and on freshly stranded plants along shore. Immatures develop inside submersed stems that break away after being cut by adult feeding and float to shore where the immatures complete their development. This species was imported into quarantine in 1987 as *Bagous australasiae* Blackburn. Later, Dr. C. W. O'Brien compared it with type specimens in the British Museum and determined that is was a new species. Studies have shown that field populations are stenophagous, with hydrilla being the primary host plant. Development in the laboratory was restricted to hydrilla and some of its relatives. It is believed that this weevil will be highly destructive to hydrilla with little risk to native plant populations. During 7 years of foreign exploration, no other insect species was found to be as damaging to native populations of hydrilla. Permission is thus requested to release it from quarantine for control of hydrilla. Another species of *Bagous*, *B. affinis* Hustache, and a leaf-mining fly, *Hydrellia pakistanae* Deonier, were released in Florida in 1987. The weevil was temporarily established during a lake drawdown in northern Florida in 1989, but it has not been permanently established. The fly is proving difficult

to establish, although perhaps increased efforts during the summer of 1989 will be fruitful. A second leaf-mining fly, *Hydrellia* n. sp. A, was released in south Florida during August 1989.

Taxonomic Position of the Biological Control Organism

The identification as *B. australasiae* (one of three described species of *Bagous* in Australia) was initially made by Dr. E. C. Zimmermann, Canberra, Australia, the foremost weevil taxonomist in Australia, and by Dr. C. W. O'Brien, Tallahassee, FL, the foremost aquatic weevil taxonomist in the United States. Their identifications were based on named specimens in the Australian National Museum. Dr. O'Brien, however, requested that the type specimen of *B. australasiae* be sent to him from England for comparison with the specimens of these authors. He found that the species of these authors was undescribed and that *B. australasiae* was a species collected by Dr. Balciunas on a floating plant, *Nymphoides indica* (L) Kuntze. These authors had been aware that there were two species but believed that the species on *N. indica* was the new one. *Bagous* (Curculionidae: Erirrhininae: Bagoini) is a cosmopolitan genus that included about 127 species in the Coleopterorum Catalogus in 1934. There were 66 species in the Palearctic Region, 22 in the Ethiopian, 14 in the Oriental, 3 in the Australian, and 22 in the American Region. There are now 33 described species in the United States according to O'Brien and Wibmer (1982).[1] Dr. O'Brien estimates that probably only 25 percent of the oriental species have been described, and he has many species that he will describe in his forthcoming revision of the Indian *Bagous*. Several additional new Australian species have been discovered during these studies.

The known host plants of *Bagous* are aquatic or semiaquatic plants except sea purslane, which lives on sand dunes. These weevils are of such little economic importance that true larval host plants have been reported for very few species. No host plants were reported for the Australian species. There is one highly suspect report of larvae of an unidentified Indian species attacking rice and two reports of a Japanese species attacking young vegetables planted in rotation with rice. Adult weevils in Japan fed briefly on the plants after they emerged and found their host plant absent because the field had not been flooded. These are the only reports found that indicate damage to economic plants by *Bagous*. Rice and the vegetables were included in the host range tests.

Adults are generally nocturnal. They are rarely collected except by black-lighting, which has often produced large numbers with no host information.

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[1] O'Brien, C. W., and Wibmer, G. J. (1982). "Annotated checklist of the weevils (Curculionidae *sensu lato*) of North America, Central America, and the West Indies (Coleoptera: Curculionidae)," Memoirs of the American Entomological Institute, Number 34.

Larvae feed internally or externally on the stems and leaves or in tubers and other underground structures. Pupation may occur within plant tissues, on the leaves, or in moist soil.

Geographic Distribution

Bagous hydrillae has been collected at 26 different sites in Australia: Fogg Dam and Yellow Water Billabong in the Darwin vicinity (Northern Territory); Lake Mondarah and Lake Mary Kathleen near Mt. Isa (western Queensland); many sites near Brisbane (southern Queensland); many sites near Townsville (northern Queensland); and near Grafton (New South Wales) (Figure 1). This distribution represents a range of 17° 31' latitude (12° 30' to 30°) and 22° longitude (130° to 153°). However, the temperatures throughout this range are extremely mild compared with those in the United States. Climadiagrams for the collection areas in Australia and for scattered locations in the United States were compared.[1] The climadiagrams of the colder Australian locations compare favorably with those of Jacksonville, FL, although winters appear to be slightly colder in Florida. The daily minimums of the coldest month averaged 6.2 °C at Grafton (NSW) and 19.6 °C at Darwin (NTR). They averaged 7.4 °C at Jacksonville. The peninsula of Florida from Jacksonville south should be highly favorable to this species.

The exact distribution of an organism in a new country is not entirely predictable, but without doubt, this weevil will not establish in Canada or the Northern areas of the United States with their harsh, long winters. It is doubtful if it will be able to establish in the northern portions of the Southeastern United States except possibly in coastal areas. The alligatorweed flea beetle, which was introduced from an area south of Buenos Aires, Argentina, has permanently established only as far north as coastal South Carolina near Charleston. When the climadiagrams from Argentina are compared with those from Australia, the Argentine climadiagrams illustrate slightly colder winter means than those at any of the Australian locations.

Host Plants

Extensive collections were made in Australia to determine the natural host range of *Bagous hydrillae*. Large-scale use of Berlese funnels allowed sampling of over 40 plant species and many locations. Berlese funnels are extractors that use the heat from light bulbs to slowly dry plant material, thus forcing insects out and down a funnel into a liquid-filled jar. This extraction method (compared with visual examination and dissection of the plants) recovers adults

[1] Walter, H., and Lieth, H. (1960). Klimadiagramm-Weltatlas. Gustar Fischer Verlag, Jena, DDR. No pagination.

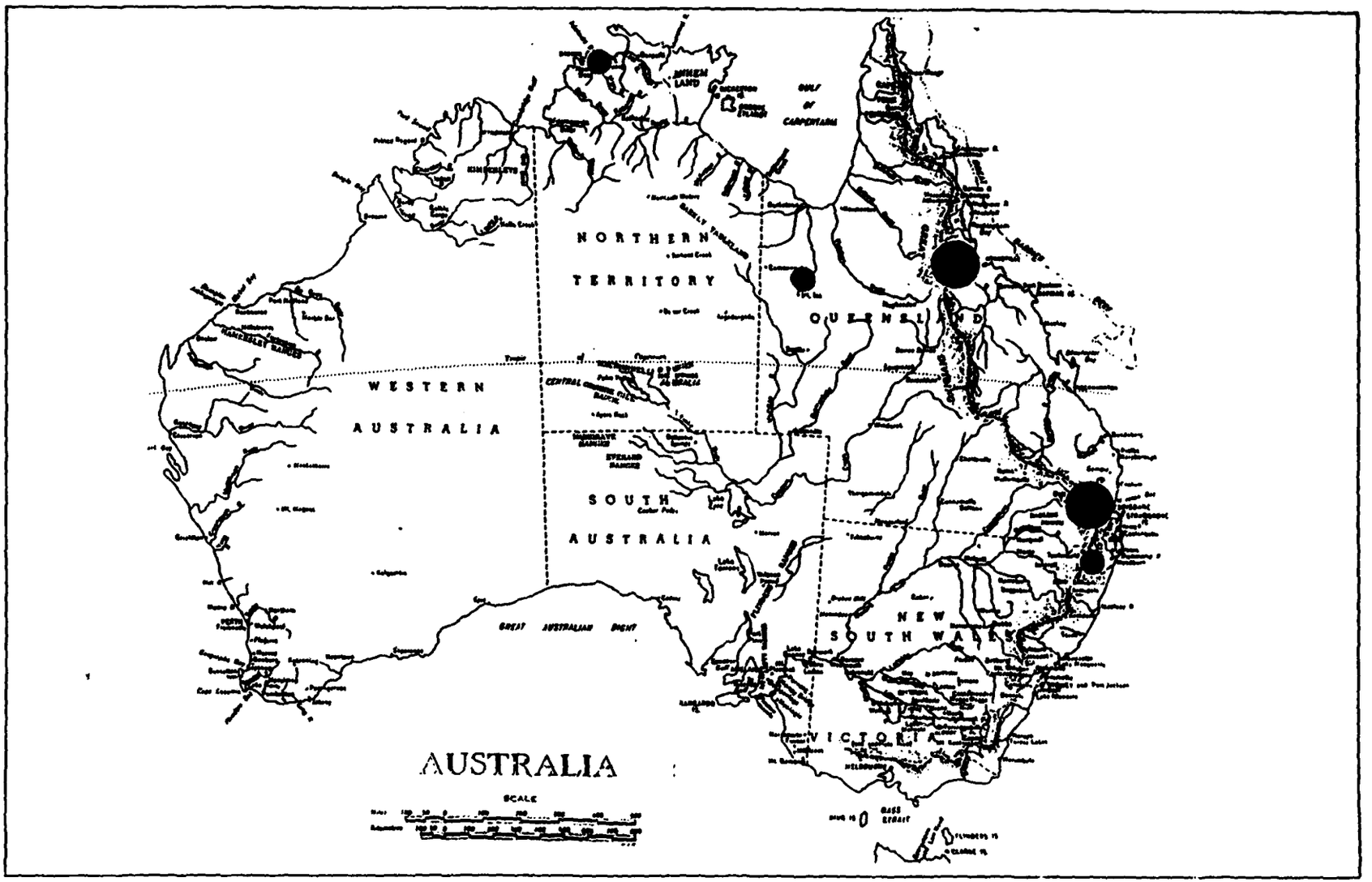

Figure 1. Collection sites for *Bagous hydrillae*

and larvae even when their numbers are small, but there is an elevated risk of false positives because of the large volume of plant material extracted. Two small sprigs of hydrilla overlooked and intertwined in a kilogram of a test plant might supply several insects for the sample. Efforts were made to ensure clean samples, but discovery of small numbers of insects in only a small proportion of the samples for a plant species should be viewed with skepticism.

The plant species collected in Australia for examination and the number of samples of each through 1988 are listed in Table 1. Sampling during 1987 and 1988 was focused upon species in the Hydrocharitaceae and related families (see Appendix A for plant relationships). Results through July and December 1988 for species on which *Bagous hydrillae* was found are presented in Tables 2 and 3. Small numbers of larvae and adults (maximum 37), some or all of which may have been contaminants, emerged from 5 of the 45 plant species. Two of the plant species, *Najas tenuifolia* R.Br. and *Vallisneria gracilis* F.M.Bailey, produced high weevil populations at one and two sites, respectively. Seventy-eight percent of all weevils were collected from hydrilla.

All sites where weevils were found in plants other than hydrilla were sites where hydrilla was present or had been previously collected. Sites where hydrilla was not present did not have *Bagous hydrillae*. Two samples provided 911 of the total 1,358 weevils on *V. gracilis* in southern Queensland. The samples were collected at two sites during extreme drought periods when receding water exposed the normally completely submersed plants. The exposed leaves formed surface mats extending to shore. At both sites, the hydrilla population had crashed and little was available for the weevils. In north Queensland, all weevils on *V. gracilis* came from one site and mostly from two of six samples (129 of 159 total). Other samples of *V. gracilis* with smaller numbers of weevils were usually collected near the shoreline during winter when hydrilla populations were low. During summer (January-April) when hydrilla was most available, weevil infestation was highest on hydrilla. Interestingly, no weevils were collected from a total of 11 samples of *Vallisneria gigantea*, a species similar to *Vallisneria* familiar to these authors. The same drought-low hydrilla conditions were present when the *N. tenuifolia* sample with a high weevil infestation was collected in north Queensland (199 of a total 226). In addition, that sample was set up for extraction by a new employee during the absence of Dr. Balciunas, who was on home leave, and may have been contaminated. *Najas* and hydrilla are quite similar species that are often confused by fishermen in Florida. Only 7 additional samples from a total of 76 samples of *N. tenuifolia* in north Queensland produced weevils, and those samples averaged only 7.3 weevils per kilogram of plant. In south Queensland, 3 of 18 samples produced weevils and averaged 3.3 weevils per kilogram of plant.

These field studies in both north and south Queensland by two researchers (Matthew Purcell assisted Dr. Balciunas in Brisbane, Australia) over a 4-year period have proven that hydrilla is the principal and perhaps only host plant of *Bagous hydrillae*. During periods when hydrilla plants were scarce or not

available, usually during winter and during droughts, weevils were collected several times in relatively large numbers from *N. tenuifolia* and *V. gracilis*. Weevil adults produced on stranded hydrilla had attacked these plants when they returned to the water and found little hydrilla. It is doubtful, however, if many of the larvae on these two submersed plants would have survived to produce adults. Little plant material of either species was found stranded along the shoreline where larvae developed in stranded hydrilla. Because the life cycle is not completed in submersed plants, it would appear that most larvae in submersed plants other than hydrilla were doomed. Hydrilla, on the other hand, often formed large windrows along shore. In fact, the amount of stranded hydrilla was often used as an indicator of the size of the weevil population.

Life History

The life history was studied in the laboratory in Australia. The life cycle from egg to adult took approximately 2.5 to 3 weeks. Females oviposited eggs singly (occasionally, two eggs) in a cavity excavated in the stem, usually within 1 mm of a node. A single female oviposited up to 20 eggs per day. Eggs were deposited in submersed hydrilla, but they were also deposited in hydrilla out of water under high humidity in laboratory cages. In the field, it is doubtful if many eggs would be deposited in stranded hydrilla, which would rapidly dry or decompose. After 3 to 4 days, the first instar hatched and usually burrowed down the stem. The final instar caused the most damage, destroying approximately 15 cm of stem by its burrowing activities. After 1 or 2 days as a prepupa, a naked pupa was formed. In the laboratory, *Bagous hydrillae* often pupated in crowns, tubers, and stems of hydrilla out of water, but larvae preferred to leave the plant and pupate on moist filter paper or in a vermiculite soil mixture. Pupae were present in the field mostly in stranded hydrilla stems along shore but also in soil beneath the hydrilla. Adults fed on hydrilla leaves and stems causing small, irregular holes and lesions. They fed on both submersed and stranded hydrilla. Stems were often severed by feeding, which produced a "mowing effect" on submersed hydrilla. Adults are not able to swim underwater, and they are also poor surface swimmers. They must crawl underwater on a plant. This limits their attack to mats that have reached the surface. Adults appeared to prefer to spend most daylight hours beneath the water surface, emerging and beginning to fly around at dusk. Adult longevity was 60 to 80 days.

Mortality Factors

Biological mortality factors are unknown in the field, but both flooding and drought appear to be major abiotic mortality factors. The fungus *Beauveria bassiana* killed small numbers of adults during shipments and during rearing in the quarantine colonies of these authors.

Effects of Organism on Host Plant

Larval and adult feeding cause fragmentation of stems. Feeding activities of large populations caused partial defoliation and fragmentation in the field. Commonwealth Scientific Industrial Research Organization observers in Brisbane attributed the disappearance of all hydrilla within a meter of the surface at Atkinson Dam to a high population of *Bagous hydrillae*. This species was the most damaging to hydrilla of the eight insects studied in the laboratory.

Potential Control Value

Goeden (1983) revised Harris' scoring system for determining the potential effectiveness of a biocontrol agent.[1] Goeden's system is presented here:

Initial Assessment of Destructiveness in Native Range	
Direct damage under field conditions	
Destruction of vascular or mechanical support tissues as an endophage	6
Indirect damage inflicted	
None	0
Phenology of attack	
Limited period of attack, but increasing host-plant susceptibility to competition from other plants	4
Number of generations	
Two or three generations a year, climate permitting	2
Number of progeny per female per generation	
<500	0
Extrinsic mortality factors	
Natural control largely effected by nonspecific enemies or abiotic ecological factors	0
Feeding behavior	
Gregarious or colonized feeders	3
Distribution	
Covers about three-quarters of the range of the target weed (in Australia)	4
Subtotal	19
Suitability as a Biological Control Agent	
Host-plant source of insect	
Obtained from the target weed species	6
Ease of culture	
Culture difficult on restricted developmental stage of host plant	2

[1] Goeden, R. D. (1983). "Critique and revision of Harris' scoring system for selection of insect agents in biological control of weeds," *Protection Ecology* 5, 287-301.

Potential safety		
Unreported as a plant pest, no plant pest in the same genus		6
Host-plant specificity		
No feeding on critical test plant in lab		6
	Subtotal	20
Potential Effectiveness in Area of Introduction		
Evidence of effectiveness as a control agent		
First use		0
Ecoclimatic similarity		
Ecoclimate of native range only partly similar to that of area of introduction		3
Colonization history of agent		
Absence of target weed in area of introduction		0
	Subtotal	3
	Total	42

Goeden stated that any candidate scoring between 20 and 50 points would probably be only partially effective as a biocontrol agent and would have to be complemented by other agents. This species will be a member of a complex of agents.

2 Host-Specificity Experiments

Initial host specificity tests were conducted in Australia during 1986. Results indicated that laboratory feeding and development were restricted mostly to plants in the hydrilla family Hydrocharitaceae or close relatives. Testing finished at the end of 1986 when approval was obtained to ship the weevils to quarantine. Two shipments of adults (and immatures produced in transit) were sent into Gainesville early in 1987. They had been collected near Brisbane. Quarantine testing over an 18-month period expanded the test plant list to include crop and ornamental species, but concentrated on native aquatic species in the genera fed upon in Australia.

Materials and Methods

Australia

The host-specificity studies consisted of two parts: (a) no-choice feeding tests with adults and (b) no-choice oviposition and larval development tests. Most of the test insects were from laboratory colonies established late in 1985.

In no-choice adult feeding tests, a pair of weevils was confined in a small plastic cup with a small portion of a single test plant. After 24 hr, the weevils were removed and the damage to the test plant scored on a scale of 0 to 10. Usually 40 to 50 replicates were run simultaneously for each test plant species. Hydrilla was treated as a test plant; it was not used as a control tested simultaneously with the test plants (Table 7).

No-choice oviposition and larval development tests were combined by exposing 10 pairs of adults to 20 g of the test plant, which had been placed on moist paper toweling in a covered plastic box (19 by 19 by 12 cm). After 3 days, adults were removed, and eggs oviposited in or on the test plant were counted. The plant material with eggs was then returned to the container and monitored daily. Fresh material was added as necessary. Dead larvae were counted and removed. After 2 to 3 weeks, the late-third instars, prepupae, and pupae that appeared on the moist toweling were removed and placed in petri

dishes containing a moist sterilized soil/vermiculite mixture. As the adults emerged in the petri dish, they were counted and preserved. Since each test took over a month, the study was restricted to plant species that had shown some damage in the feeding tests. The oviposition/larval survival tests were repeated for each plant species until there were four replicates (Table 9).

Quarantine

No-choice feeding tests with adults were conducted in several ways. Initially, they were conducted as in Australia with small plastic cups. However, the cups were held for another 3 days after the initial hydrilla was removed and replaced after 1 day. Feeding was scored as in Australia, but an estimate was also made of the cubic millimeters eaten. Equal numbers of hydrilla cups were included in every test as a simultaneous control. Crop or ornamental plants were tested in small vases buried in moist sand in 3.8-ℓ (1 gal) glass jars or in 15-cm-diam Plexiglas cylinders. Stems of hydrilla were held on moist sand in similar containers. Aquatic plants and the hydrilla controls were tested both in a small amount of water in 3.8-ℓ jars and in covered plastic boxes (31 by 21.5 by 6 cm) on moist paper toweling similar to the Australian oviposition tests. Some choice tests, with and without hydrilla, were conducted in both ways. Others were conducted by burying multiple vases of terrestrial test plants in dry sand in either a 38-ℓ aquarium without hydrilla or in a 7.5-ℓ glass cylinder with a petri dish of hydrilla in water. A vase planted with multiple crop plants was also tested in the 7.5-ℓ cylinder without hydrilla. Both newly emerged and older adults and different ages of crop plants were tested.

All containers except the covered plastic boxes were capped with fine mesh cloth or with saran mesh. Feeding was estimated visually under a stereomicroscope in cubic millimeters or in square millimeters, which were converted to cubic millimeters by multiplying with 0.1 mm, the estimated leaf thickness. Most tests were 3 or 7 days long, but some were 1, 4, 5, or 6 days. The number of replicates and insects per replicate varied depending upon the number of adults and plants available. Most tests had either three or six replicates with six females each. Other tests had 162 adults, no replicates; 52 adults, 3 replicates; 5 adults, 3 or 5 replicates; or 6 adults, 2 replicates. Most tests had hydrilla controls run simultaneously. Means in the paired-choice with host feeding tests were compared with a paired t-test ($p = 0.05$) after transformation with $\sqrt{x + 0.05}$.

Because females feed on the plant when ovipositing, oviposition tests were dual feeding/oviposition tests. Eggs and larvae were counted, while feeding was estimated. Care was taken to disturb the eggs as little as possible while tearing the plant tissue to observe them. Means in the paired-choice with host oviposition tests were compared with a paired t-test ($p = 0.05$) after transformation with $\sqrt{x + 0.05}$. Plant material containing eggs was held for larval development on moist sand in 3.8-ℓ jars or in plastic boxes. In some oviposition tests in water, material was held in the jars to determine if the larvae

would develop in the submersed plants or was held in the jars until the plants with mature larvae were removed to sand.

An oogenesis test to determine if females would produce viable eggs after feeding only on test plants was conducted with females that had not fed on hydrilla. Females were collected in rearing aquaria from which the dried hydrilla had been removed before the adults emerged and had been replaced with the test plant. Three replicates each with five females were initiated in the plastic boxes with *Elodea canadensis* L.C.Rich, *Najas guadalupensis* (Spreng.)Magnus, *Vallisneria americana* Michx., and hydrilla. The plant material was changed and the eggs and neonates counted at intervals of 4 to 11 days for 24 to 31 days. All eggs were held to determine their viability.

To determine if one or more generations could be completed on the above three plant species plus *Egeria densa* Planch. under simulated natural conditions, adults were placed on plant material in 3.8-ℓ jars with water, one plant species per jar. Approximately every 20 days, the exposed plant material was removed to moist soil in a covered 3.8-ℓ jar simulating stranding along shore. All adults of each generation were combined in a new jar with the test plant in water. The tests were started with 5 to 18 females per plant species.

To determine if development could be completed in plants in water, mixed adults were confined with test plants rooted in cages in the greenhouse. Hydrilla and *V. americana* were in plastic cylinders submersed in Min-O-Cool tanks; *N. guadalupensis* was in a 37.9-ℓ aquarium; and *E. canadensis* was in a 473-ℓ aquarium. The numbers of mixed adults and the total days exposed to each plant are as follows: *E. canadensis*, 117 adults, 29 days; *N. guadalupensis*, 117 adults, 34 days; *V. americana*, 144 adults, 48 days; and hydrilla, 182 adults, 41 days. Leaf or stem sections found floating on the water surface were removed periodically to moist soil in 3.8-ℓ jars to simulate natural stranding along shore. The cages were observed for adults at that time. Adults were collected from the soil jars as they emerged. At termination of the experiment, all submersed plant material was examined under the stereomicroscope for larvae, pupae, and adults. Parent adults were marked by lightly scratching their sterna with a pin.

A multichoice oviposition and larval development test was conducted in a large screened cage, 7.3 m^3, in a greenhouse. The bottom of the cage contained water about 25 cm deep. Four plant species of approximately equal plant volume were randomized to positions in each of three blocks. The plants were not rooted or anchored. A small amount of each species was placed in water in a 3.8-ℓ jar as a control. Adults, 312 newly emerged and older, were marked, and then equal numbers were released on Styrofoam floats in the center of each block. Seven adults were also placed in each jar. After 34 days, the plant samples were removed from both the cage and the jars and placed on nylon mesh covering plastic dishpans containing soapy water. The dishpans were placed individually in wooden glass-topped cages. As the plant material dried, larvae and adults dropped to the water or adults crawled around the cage. They were counted and the means of total insects were compared

after transformation ($\sqrt{x + 0.05}$) with the General Linear Model procedure and separated with Waller-Duncan k-ratio t-test (SAS for personal computers).

Aquatic test plants were generally collected in waterways near Gainesville, FL. Hydrilla for tests was usually used within 2 weeks of collection. In Australian laboratory tests, hydrilla was not accepted for oviposition after 5 days. However, in Florida, colonies were often reared with hydrilla held in outdoor pools for a month or more after field collections. *Elodea canadensis* was purchased from an aquatic plant dealer in Wisconsin and from a biological supply house in South Carolina. Crop and ornamental plants were grown in a greenhouse from seed or purchased locally.

Results

Australia

Results of the no-choice adult feeding tests are presented in Table 4. Feeding was negligible on the 25 species outside the hydrilla family except on four species: *Ceratophyllum demersum* L., *Cabomba caroliniana* A. Grey, *Najas tenuifolia*, and *Potamogeton* sp. On *Potamogeton* sp., it was still marginal with no scores above 3 recorded. Feeding scores on the five species in the hydrilla family were similar to scores on hydrilla. Two of those species, *Egeria densa* and *Elodea canadensis*, are introduced nuisance plants in Australia, but the other three, *Blyxa* sp., *Ottelia alismoides* L. Pers., and *Vallisneria* sp., are native to Australia.

Results of the no-choice oviposition and larval development tests, which included the nine species eaten in the no-choice tests, five other species in the same genera, and four additional species are presented in Figure 2. When oviposition was plotted against percent adult emergence from the eggs, hydrilla was clearly separated from the other laboratory host plants (Figure 3).

Quarantine

Results were similar to those in Australia. Feeding was low on most plants outside of the hydrilla family except in the same genera eaten in the Australian experiments (Table 5). Two plants with succulent leaves, *Sedum* sp. and *Sesuvium portulacastrum* (L.)L., were moderately eaten in one test but not in others. The feeding on *S. portulacastrum* in a no-choice test, about 35 percent of the feeding amount on hydrilla, was only on the day of exposure. Three days later, the feeding was only 5 percent of hydrilla feeding. Minor to moderate feeding on succulent leaves has also been observed in the laboratory with other biocontrol agents, for example, waterhyacinth weevils and the hydrilla tuber weevil. Weevils nibbled on leaves of radish, cucumber, and lettuce in two tests, but did not feed on them in other tests. *Ceratophyllum demersum*

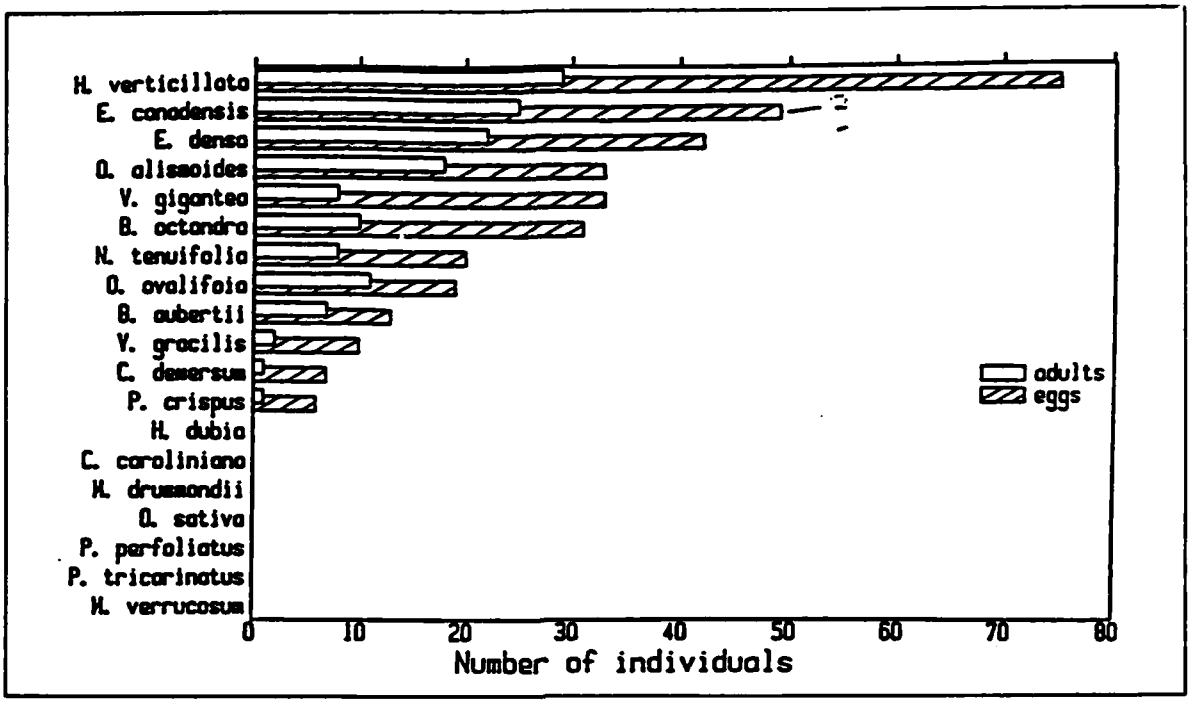

Figure 2. Bar graph depicting average number of eggs and adults of *Bagous hydrillae* produced on each test plant species. Abbreviations for each test plant species (see Table 4 for complete names) are on the left

and *Cabomba caroliniana* were eaten much less in these tests than in Australia. This may be because they were exposed for 7 days compared with 1 day in Australia; for example, weevils may have fed at initial contact but soon quit. Minor feeding was obtained on the weed *Pistia stratiotes* L. after 1 day, but declined after 3 days. Minor feeding was also obtained on *Nymphoides aquatica* (S.G. Gmel.) Kuntze and *Sagittaria* spp. No more than nibbling was found on 17 other plant species, including rice.

Plants in the hydrilla family along with their close relatives *Najas guadalupensis* and *Potamogeton crispus* L. were moderately to heavily eaten in most experiments. Feeding generally declined in choice tests with hydrilla (Table 8). A few eggs were deposited on *P. crispus*, one of the three species of *Potamogeton* tested, but the larvae did not complete development (Table 8). *Potamogeton crispus*, an introduced nuisance plant in the United States, is an associate of hydrilla in Australia. Feeding was low on the two native species of *Potamogeton*, and only one adult was produced on *P. perfoliatus* L. Feeding and oviposition on *N. guadalupensis*, which were high in no-choice tests, were reduced when the plant was paired with hydrilla, although the results were not statistically significant (Table 8). Ten adults were produced on that species compared with 43 on the paired hydrilla. Feeding on *Vallisneria americana* was lower than on hydrilla both in and out of water, but oviposition and larval survival were high even exceeding that on hydrilla (Tables 6, 8, and 10). However, in a natural situation, few larvae would

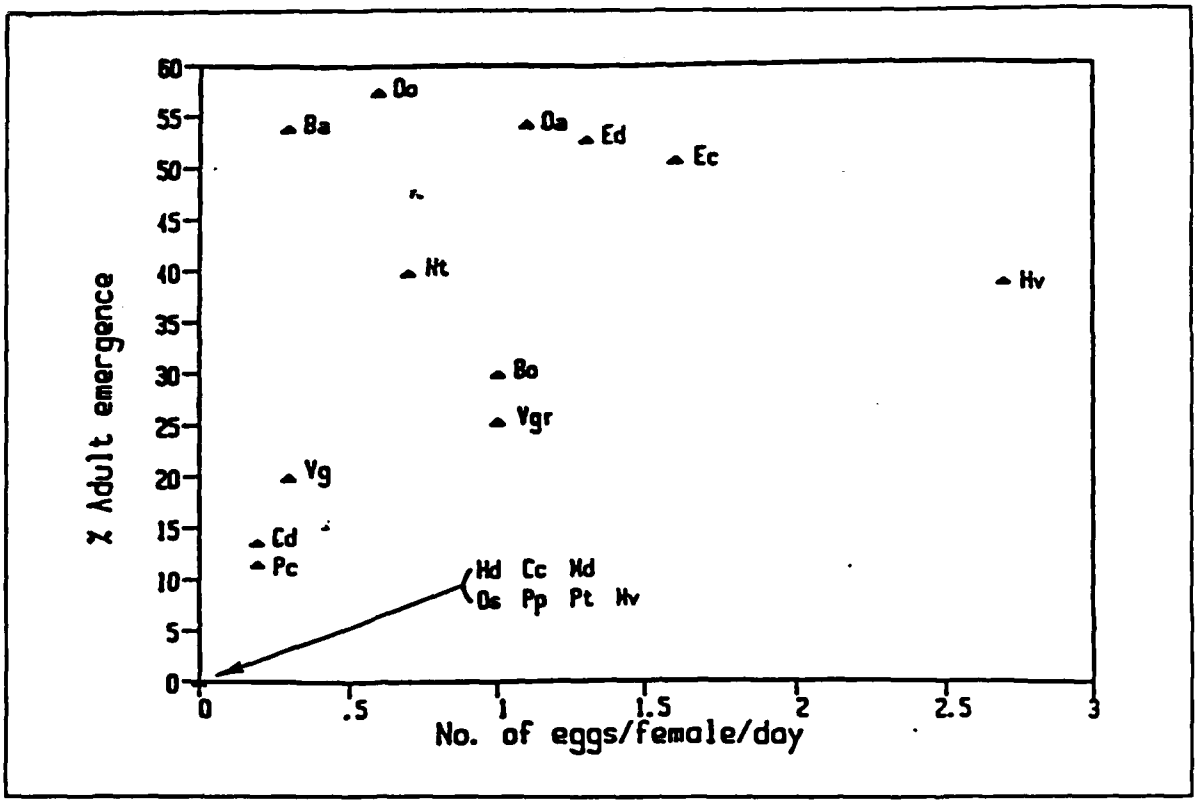

Figure 3. Graph illustrating suitability of each tested aquatic plant species as a host for oviposition and development of *Bagous hydrillae*. Plant species names are coded by first letter from genus and species (see Table 4 for list of plant species)

survive because the adults did not sever the leaves as they did on hydrilla. Feeding estimates on *Limnobium spongia* in no-choice tests were high only because a spongy cell layer on the underside of the leaves was eaten (Table 6). The destruction of these large air-filled cells that act as floats for young leaves resulted in a large estimate of cubic millimeters eaten, but little damage to the leaf. The cell layer is often eaten by native snails and other organisms. In fact, finding leaves with undamaged floats to test was difficult. As the plant matures, it produces aerial leaves without floats. When the cell layer was removed before testing, the beetles fed little (Table 6). Substantial feeding, oviposition, and larval survival were obtained on *Egeria densa* (Tables 8 and 10), an important introduced nuisance plant from South America. *Elodea canadensis* was eaten more heavily than hydrilla in both no-choice (Table 6) and paired-choice tests (Table 10), but oviposition and larval survival were generally lower on it (Table 10). The importance of the results on these two species will be discussed in more detail later.

Oogenesis tests with females that had never fed on hydrilla confirmed that females could produce viable eggs when feeding on *N. guadalupensis* (1.7 eggs/female), *E. canadensis* (7.1), *V. americana* (26.2), and hydrilla (7.8). These results were extremely low for hydrilla, suggesting that females may have been stimulated to produce wing muscles in this test rather that eggs.

The two are mutually exclusive. The test did confirm, however, that females could produce eggs on several plant species. Subsequent to the oogenesis tests, small numbers of weevils were reared through two generations on *E. canadensis*, *E. densa*, and *N. guadalupensis* and through eight generations on *V. americana*. The adults in these tests were held on plants in water, but the exposed material was placed on moist soil for weevil pupation.

The Australian field studies and the larval development tests of these authors indicated that adults were not produced on plants that remained submersed. In most tests, however, the plants were not rooted and were floating in the water. In greenhouse cages with rooted plants, no adults were produced on the submersed test plants, and only two were produced in the hydrilla cage. The two on hydrilla were probably produced on floating stem sections overlooked near the sides of the cage since no pupae or mature larvae were found in the submersed stems when the test was terminated. Females in the cages oviposited, however, because floating plant sections of all four species that were periodically removed to cages with moist sand did produce adults. The numbers produced were as follows: *E. canadensis*, 29; *N. guadalupensis*, 26; *V. americana*, 7; and hydrilla, 23.

Larvae were found in the large greenhouse cage in all four plant species, but the largest number, 81, was in *N. guadalupensis*. Hydrilla had 18 larvae, *V. americana* 17, and *E. canadensis* 11. Only the mean for *N. guadalupensis* was significantly different. In the control jars for this experiment, *N. guadalupensis* was not attacked, *E. canadensis* had larvae but produced no adults, and both *V. americana* and hydrilla produced adults in material removed to moist sand. *Elodea canadensis* was heavily attacked in the large cage by a native *Hydrellia* and a midge (naturally infested in Wisconsin when it was collected). In fact, native insects on all plants (all were field collected) were much more abundant than *Bagous hydrillae*. A total of 538 caterpillars, 76 midge larvae, and 146 *Hydrellia* fly larvae were recovered from the cage compared with 132 *Bagous hydrillae* larvae. Total insect numbers were high, but it is not believed that interspecific competition was an important factor in the results because there was sufficient total plant material. These results illustrate, however, the large native herbivore load on native plants.

3 Discussion

The Australian field studies have proven that *Bagous hydrillae* is a major destroyer of hydrilla (Figures 4-6) and that its biology is closely adapted to hydrilla. Adults cannot swim underwater and are poor surface swimmers, but hydrilla forms large surface mats on which they can land and crawl underwater. Adults feed mostly on stems that are relatively narrow in hydrilla and can be easily cut by adult feeding. These stem portions containing larvae float readily and carry the larvae to shore where they safely pupate.

Because the initial laboratory tests in Australia demonstrated that *Bagous hydrillae* would feed and breed on several nonhost plants, aquatic plant surveys became the focus of the Australian program after the second year. This was the most intensive survey of alternate host plants of which these authors are aware that has been conducted for a nuisance aquatic plant biocontrol agent as well as for terrestrial biocontrol agents. Samples were collected over a 4-year period. Larvae were obtained only on hydrilla from 1985 to mid-1986. Increased sampling of high risk plant species (hydrilla relatives and others eaten in the laboratory) and an extreme drought during the Australian spring (September-October) of 1986 and into 1987-1988 produced larvae in scattered samples of several plant species. During the drought, hydrilla populations were reduced, and normally submersed species were exposed in large mats in shallow water along shore. The ability to survive in nonhost plants during unfavorable periods would be beneficial for long-term survival of the species.

The following plant species (or a similar species in Australia) produced adults in the laboratory, and larvae emerged from field material. The importance of these results will be discussed for each of the following species:

Ceratophyllum demersum. Only two adults were reared from this species in quarantine, and the average was one adult in Australian tests. The two quarantine adults developed from overlooked eggs because no eggs were found during examinations. Field infestations were scattered and low. Feeding in quarantine was light after the first day. This weedy species is usually completely submerged and would rarely be exposed to weevils except when growing with hydrilla. There would be no risk to field populations of this plant.

Potamogeton spp. One adult was produced on the native *P. perfoliatus* in quarantine, but none on that species in Australian tests. One larva was

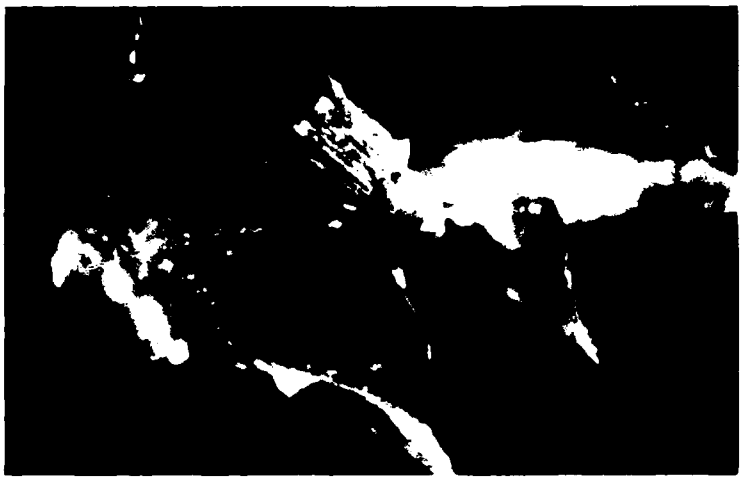

Figure 4. *Bagous hydrillae* adult on hydrilla leaf

Figure 5. *Bagous hydrillae* adult feeding damage on hydrilla stem

Figure 6. *Bagous hydrillae* larvae in hydrilla stem

collected on it in Australia. Feeding was light to moderate in quarantine. No adults were produced on the introduced weed *p. crispus* in quarantine and only an average of one in Australian tests. A total of eight larvae were collected on it in Australia. None were produced or collected on four other species of *Potamogeton*. Pondweeds would be available to adults in the field, but there would be no risk to plant populations.

Limnobium spongia. Six adults were produced in quarantine in one of four tests. This native species is not present in Australia. Feeding was heavy on the spongy, air-filled layer of cells (aerenchyma) that act as a float. The green portion of the leaf was not eaten. This spongy layer is heavily eaten by native herbivores, and it was extremely difficult to find undamaged plants for testing. To prevent herbivory on this layer, plants had to be grown in cages. Adults fed little on the thick stems, which would not be cut, even with heavy feeding. Larvae on this plant would not reach shore in the field. This plant is the host for the most commonly collected native *Bagous, B. lunatoides*, in Florida. Larvae of that species mine both stems and leaves and pupate in the plant. *Bagous hydrillae* does not present a risk to plant populations in the field.

Egeria densa. This is a major introduced South American nuisance plant that has been listed as a target for biological control. Attack on this species would be beneficial. Adults were produced both in quarantine and in Australian laboratory tests. Feeding was moderate and oviposition high. However, even though this species appears to be an excellent alternate host plant, only one larva emerged from 89 samples collected in Australia. The side where that larva was collected also had infested hydrilla. This laboratory host does not appear to be an acceptable field host.

Najas guadalupensis. This species and *N. tenuifolia* in Australia produced adults in quarantine and in Australian laboratory tests. A total of 10 adults were produced in quarantine and an average of 9 adults in Australia. Oviposition and larval feeding was high, but generally few larvae completed development. Only one field sample in Australia produced large numbers of larvae, even though this was one of the intensively collected species (76 samples). This may have been a contaminated sample since it was collected by relatively new assistants while Dr. Balciunas was in the United States. *Najas guadalupensis* is generally completely submersed lying just beneath the surface. This weedy species, which was the number one submersed weed in the Southeastern United States before the introduction of hydrilla, would rarely be available to adults except when mixed with hydrilla. The lack of field infestations in *N. tenuifolia* in Australia and the growth habit of *N. guadalupensis* indicate that plant populations would not be at risk.

Vallisneria americana. This species was an excellent host in quarantine, and both *V. gigantea* and *V. gracilis* were hosts in Australian tests. Several large infestations of larvae were found in *V. gracilis* in Australia, although generally infestations were low. These infestations occurred during drought periods when leaves were exposed by low water. No infestations were found on *V. gigantea*. *Vallisneria americana* is generally a completely submersed

species. Although its leaves are usually near the surface, it rarely forms surface mats that would be available to the adults. Additionally, adults in quarantine feeding tests did not cut the leaves, and larvae cannot mature in the submersed leaves. The only risk that *Bagous hydrillae* would present to this species would be during drawdowns when the plants were fully exposed. At that time, the plants, which reproduce from seeds, would be killed by drying.

Elodea canadensis. This species produced adults in both quarantine and Australian laboratory tests. No larvae were collected in plants in Australia, but this species was present only in colder areas outside the apparent range of the weevil. The growth habit of the plant is like that of hydrilla, and field infestations might occur if this species were present with hydrilla. However, this species is a cold-water plant only marginally present in the southeast. Even though this species was attacked in the laboratory, it might not be in the field, even if present with hydrilla. *Egeria densa*, which was an equally accepted laboratory host, was not a good field host in Australia. Although occasional damage might be found on *E. canadensis*, there should be no risk to its populations by *Bagous hydrillae*. The weevil will not survive harsh winters within the plant's native northern range.

Bagous hydrillae should cause extensive damage to dense hydrilla mats that have reached the water surface. Breakage of the stems will produce a "mowing effect," thus opening up the surface of the water. Even if damage is limited to the upper water column, it will increase waterflow in irrigation canals and increase access to motorboats. In addition, large weevil populations could be produced during drawdowns, thus providing enormous reservoirs of weevils to attack the new growth of hydrilla after the drawdowns end.

Although there may be potential for limited damage to native relatives of hydrilla, the releasing of this weevil should not be deterred. The aquatic plant species attacked in the laboratory are all fast-growing weedy species that are able to sustain large amounts of damage, as our chemical and mechanical control programs have demonstrated. Their populations are presently damaged greatly from invasion of the waterways by hydrilla and by subsequent control operations. Without the extensive field data from Australia, petitioning to release this species based upon our laboratory studies probably would not happen. However, with data from both field and laboratory, data that are consistent, it is believed that this is a safe and an effective control agent. A fourth agent for biocontrol of hydrilla would be welcomed by nuisance plant managers. Approval of *Bagous hydrillae* would present another opportunity to increase the stress on hydrilla to reduce its impact on our native flora, fauna, and waterways.

4 Conclusions

The Australian weevil *Bagous hydrillae* attacks hydrilla stems. Adults feed externally and larvae mine internally. Damaged stems break away and float to shore where the larvae mature and pupate. Heavy adult feeding produces a "mowing effect" on the hydrilla mat. This weevil has a relatively wide geographic range in Australia, but the climates at all collection sites were similar to that of Jacksonville, FL, or warmer. This species will not be useful in the northern United States except possibly in an inundative release program. Extensive field sampling of aquatic plants from 1985-1988 proved that hydrilla was the primary host plant, although several additional submersed species were larval hosts during periods when hydrilla was scarce (e.g., during droughts and winter). It is doubtful if many larvae mature in these plant species, however, because little plant material was found along with hydrilla stranded on shore where the larvae pupate. Larvae do not mature in submersed stems. The life cycle took about 3 weeks. The potential control value estimated by Goeden's (1983) system was 42 points.[1] *Bagous hydrillae* completed development in the laboratory on five native and one adventive plant species. Four of these six were in the hydrilla family, and the other two were close relatives in the subclass Alismatidae. All but one of these were in genera that also produced adults in Australian tests. Generally, only small numbers of larvae were recovered from plants in these genera during Australian field sampling. These plants were not cut up by adult feeding as was hydrilla. Because larvae pupate in plant material stranded along shore and not in submersed plants, *Bagous hydrillae* would not threaten these species. *Bagous hydrillae* adults might occasionally attack some native aquatic plants, but their damage should be of little consequence against the background damage from native herbivores. One of the plants accepted in the laboratory, *Elodea canadensis*, is a northern species that is most common outside the expected geographic range of *Bagous hydrillae*. It is believed that *Bagous hydrilla* has the potential to greatly increase the stress on hydrilla in southern states, where hydrilla is most abundant and is safe for release from quarantine.

[1] Goeden, R. D. (1983). "Critique and revision of Harris' scoring system for the selection of insect agents in biological control of weeds," *Protection Ecology* 5, 287-301.

Table 1
Numbers of Field Collected Samples of Aquatic Plants Examined for *Bagous hydrillae* (Through 10 December 1986)

Family	Species	Number of Samples[1]				
		QLD	SQL	NTR	NSW	Total
Pteridophyta						
Azollaceae	*Azolla pinnata?*	9				9
	Salvinia molesta	3	1			4
Marsilaceae	*Marsilea drummondii?*	36	1			32
	Marsilea mutica			1		1
Algae						
Characeae	*Chara* sp.	9				9
	Nitella sp.	3				3
Angiosperms						
Monocotyledons						
Aponogetonaceae	*Aponogeton queenslandicus?*	1				1
Araceae	*Pistia stratiotes*	6		1		7
Cyperaceae	*Eleocharis* sp.	4				4
	Cyperus sp.	1				1
	Scirpus mucronatus?	1				1
Graminae	*Leersia* sp.	1				1
Hydrocharitaceae	*Blyxa aubertii*	2				2
	Blyxa octandra	62				62
	Elodea canadensis				2	2
	Egeria densa		69	20	40	129
	Hydrilla verticillata	284	198	70	18	570
	Otellia alismoides	3				3
	Otellia ovalifolia	6	10	2	3	21
	Vallisneria gigantea	4	4	2	1	11
	Vallisneria gracilis	69	66	23	10	168
Lemnaceae	*Lemna* sp.	2				2
Najadaceae	*Najas tenuifolia*	59	14	8	4	85

(Continued)

[1] QLD = tropical Queensland, north of Rockhampton; SQL = southern Queensland; NTR = Northern Territory; and NSW = New South Wales. Each sample represents plants collected at a site on a given day. Samples may have been collected at the same site on different days or at different sites.

Table 1 (Concluded)

Family	Species	Number of Samples				
		QLD	SQL	NTR	NSW	Total
Pontederiaceae	*Eichhornia crassipes*	8	1			9
	Monochoria cyanea	1				1
Potamogetonaceae	*Potamogeton crispus*	2	16	4		22
	Potamogeton javanicus	8				8
	Potamogeton pectinatus?		1			1
	Potamogeton perfoliatus		13	5	2	20
	Potamogeton tricarinatus	22	7	5		34
	Potamogeton orchoreetus		1		2	3
Typhaceae	*Typha domingensis?*	1				1
Dicotyledons						
Cabombaceae	*Cabomba caroliniana*	4	2		1	7
Ceratophyllaceae	*Ceratophyllum demersum*	96	4	3	4	107
Convulvulaceae	*Ipomea aquatica*	13				13
Haloragaceae	*Myriophyllum trachycarpum*	15				15
	Myriophyllum verrucosum	9	5	4		18
Lentibulariaceae	*Utricularia australis*	18				18
Menyanthaceae	*Nymphoides indica*	46	17	12	2	77
	Villarsia reniformis	1				1
Nelumbonaceae	*Nelumbo nucifera?*			1		1
Nymphaceae	*Nymphaea gigantea*	20	2	1		23
	Nymphaea mexicana		2			2
Onagraceae	*Ludwigia plepoides*	12	4	2		18
Philydraceae	*Lanuginosum*	1				1
Ploygonaceae	*Polygonum decipiens?*	3				3
Total		846	438	164	93	1,541

Table 2
Summary of *Bagous hydrillae* Collections in Southern Queensland and New South Wales (January 1985-December 1988)

Plant Species	Total Samples	Samples Infested %	No. Adults	No. Larvae	Average Weevils per Sample	Average Weevils per Infested Sample	Average Weevils per kg of Plant; Infested Samples
Ceratophyllum demersum	8	12.5	14	9	2.9	23.0	13.7
Egeria densa	109	2.8	2	1	0	1.0	0.9
Hydrilla verticillata	216	32.9	1,496	4,050	25.7	78.1	52.7
Najas tenuifolia	18	16.7	0	13	0.7	4.3	3.3
Nymphoides indica	19	10.5	1	2	0.2	1.5	0.8
Potamogeton crispus	16	18.8	4	8	0.8	4.0	3.0
Potamogeton perfoliatus	15	6.7	0	1	0.1	1.0	1.6
Vallisneria gracilis	76	27.6[1]	130	1,275[2]	18.5	66.9	49.2
All other aquatic spp	57	0	0	0	0	0	0
Totals	534	–	1,647	5,359	–	–	–

[1] Seventeen of twenty-one infested *V. gracilis* samples and nineteen of seventy-one infested hydrilla samples came from plant material exposed at the shoreline or from shore.
[2] Seven hundred and fifty larvae came from one sample.

Table 3
Summary of *Bagous hydrillae* Collections in North Queensland and Northern Territory (January 1985-July 1988)

Plant Species	Total Samples	Samples Infested %	No. Adults	No.[1] Larvae	Average[1] Weevils per Sample	Average[1] Weevils per Infested Sample	Average[1] Weevils per kg of Plant; Infested Samples
Ceratophyllum demersum	99	4.0	3	11	0.1	2.8	4.5
Hydrilla verticillata	354	10.2	18	695	2.0	19.8	21.7
Najas tenuifolia	67	9.0	10	205 (6)	3.2 (0.2)	35.8 (3.2)	101.8 (7.0)
Vallisneria gracilis	92	6.5	19	140	1.7	26.5	31.8
All other aquatic spp.	398	0	0	0	0	0	0
Totals	1,010	–	47	1,051	–	–	–

[1] Number in ( ) is the number after one sample that was probably contaminated with hydrilla and was excluded. That sample was processed by a newly hired employee who erred with later samples.

Table 4
Results of No-Choice Adult Feeding Tests with *Bagous hydrillae* in Australia (1985-1986)

Host Family	Genus	Portion Used	Population Site[1]	Number of Tests	Average Score[2]	Standard Deviation	Range
Pteridophyta							
Azollaceae	*Azolla*	Whole plant	SQL	16	0.00	0.00	0 to 0
		Whole plant	KLB	30	0.57	0.90	0 to 3
Marsileaceae	*Marsilea*	Leaves and top stem	SQL	20	0.00	0.00	0 to 0
		Leaves and top stem	KLB	38	0.00	0.00	0 to 0
Parkeriaceae	*Ceratopteris*	Leaves	SQL	9	0.00	0.00	0 to 0
		Leaves	KBL	39	0.00	0.00	0 to 0
Salviniaceae	*Salvinia*	Whole "leaves"	SQL	26	0.00	0.00	0 to 0
		Whole "leaves"	KLB	39	0.00	0.00	0 to 0
Algae							
Characeae	*Nitella*	Whole plants	SQL	34	0.15	0.36	0 to 1
	Chara	Tips	KLB	31	0.10	0.30	0 to 1
		Tips	RRD	24	0.16	0.38	0 to 1

(Sheet 1 of 5)

[1] Weevil populations are coded as follows: KLB = Keelbottom Creek, North Queensland; RRD = Ross River Dam, North Queensland; SQL = South Queensland.
[2] Feeding score was based on a scale of 0 (no feeding) to 10 (maximum feeding).

Table 4 (Continued)

Host Family	Genus	Portion Used	Population Site	Number of Tests	Average Score	Standard Deviation	Range
Angiosperms							
Dicotyledons							
Ceratophyllaceae	*Ceratophyllum*	Leaves and stems	SQL	44	3.89	1.67	1 to 8
		Leaves and stems	KLB	30	1.80	1.45	0 to 6
Cabombaceae	*Cabomba*	Leaves	RRD	28	0.75	1.82	0 to 7
		Leaves	KLB	33	1.82	0.73	0 to 4
Compositae	*Cotula*	Leaves	KLB	65	0.00	0.00	0 to 0
Convolvulaceae	*Ipomea*	Leaves	SQL	14	0.00	0.00	0 to 0
		Leaves	KLB	39	0.00	0.00	0 to 0
Haloragacaea	*M. verrucosum*	Leaves and stems	SQL	42	0.36	0.62	0 to 2
	M. trachyca-rpum	Leaves and stems	SQL	23	0.40	0.70	0 to 2
Menyanthaceae	*Nymphoides*	Leaves	SQL	41	0.00	0.00	0 to 0
		Leaves	KLB	30	0.06	0.25	0 to 1
		Leaves	RRD	27	0.00	0.00	0 to 0
Nelumbonaceae	*Nelumbo*	Leaves	SQL	19	0.00	0.00	0 to 0
		Leaves	KLB	36	0.00	0.00	0 to 0
Nymphaeaceae	*Nymphaea*	Leaves	SQL	22	0.00	0.00	0 to 0
		Leaves	KLB	24	0.00	0.00	0 to 0
		Leaves	RRD	18	0.00	0.00	0 to 0

Table 4 (Continued)

Host Family	Genus	Portion Used	Population Site	Number of Tests	Average Score	Standard Deviation	Range
Onagraceae	*Ludwigia*	Leaves	SQL	43	0.00	0.00	0 to 0
		Leaves	KLB	37	0.00	0.00	0 to 0
Polygonaceae	*Polygonum*	Leaves	SQL	11	0.00	0.00	0 to 0
		Leaves	KLB	30	0.00	0.00	0 to 0
Monocotyledons							
Cyperaceae	*Eleocharis*	Leaves	SQL	20	0.00	0.00	0 to 0
		Leaves	KLB	38	0.00	0.00	0 to 0
	Scirpus	Leaves	KLB	50	0.00	0.00	0 to 0
Graminae	*Rice*	Young leaves	KLB	33	0.00	0.00	0 to 0
	Rice	Roots	KLB	34	0.00	0.00	0 to 0
Hydrocharitaceae	*Blyxa*	Leaves	SQL	11	4.91	1.45	2 to 7
		Leaves	KLB	34	5.29	2.01	2 to 9
	Egeria	Leaves and stems	KLB	35	1.89	1.94	0 to 7
		Leaves and stems	RRD	21	1.38	1.60	0 to 7
		Leaves and stems	SQL	34	2.60	1.92	0 to 7
		Leaves and stems	SQL	24	3.50	1.70	0 to 7
	Elodea	Leaves and stems	KLB	40	1.43	0.90	0 to 4
		Leaves and stems	RRD	23	1.69	1.18	0 to 5
		Leaves and stems	SQL	39	1.79	1.61	0 to 7
		Leaves and stems	SQL	16	4.10	2.10	0 to 8

Table 4 (Continued)

Host Family	Genus	Portion Used	Population Site	Number of Tests	Average Score	Standard Deviation	Range
	Hydrilla	Tips (L&S)[3]	SQL	37	6.81	1.99	2 to 10
		Tips (L&S)	KLB	38	2.50	1.74	0 to 7
		Tips (L&S)	RRD	40	2.03	1.54	0 to 6
	Hydrilla[4]	Tips (L&S)	SQL	30	3.70	2.14	0 to 9
		Tips (L&S)	KLB	32	4.60	1.98	0 to 9
		Tips (L&S)	RRD	20	2.35	1.67	0 to 6
	O. alismoides	Leaves	KLB	21	2.19	1.72	0 to 6
		Leaves	RRD	18	2.89	2.65	0 to 8
		Leaves	SQL	17	3.10	2.12	0 to 7
	Vallisneria	Leaves	SQL	36	4.08	1.95	0 to 9
		Leaves	KLB	39	1.74	1.11	0 to 5
		Leaves	RRD	26	1.90	1.35	0 to 5
Lentibulariaceae	*Utricularia*	Tips	KLB	18	0.11	0.32	0 to 1
		Tips	RRD	16	0.13	0.34	0 to 1
		Tips	SQL	13	0.62	1.32	0 to 4
Najadeceae	*Najas*	Leaves and stems	SQL	27	3.26	1.41	1 to 6
		Tips (L&S)	KLB	40	0.93	0.73	0 to 3
Philydraceae	*Philydrum*	Leaves	SQL	4	0.00	0.00	0 to 0

[3] Tips (L&S) = tips of leaves and stems.
[4] Poor quality material.

Table 4 (Concluded)

Host Family	Genus	Portion Used	Population Site	Number of Tests	Average Score	Standard Deviation	Range
Pontederiaceae	*Eichlomia*	Leaves	SQL	24	0.00	0.00	0 to 0
		Leaves	KLB	40	0.00	0.00	0 to 0
	Monochoria	Leaves	KLB	30	0.00	0.00	0 to 0
Potamogetonaceae	*Potamogeton*	*Leaves*	SQL	*34*	*0.24*	*0.61*	*0 to 3*
		Leaves	KLB	22	1.19	0.56	0 to 3
Typhaceae	*Typha*	Leaves	SQL	25	0.00	0.00	0 to 0
		Leaves	KLB	39	0.00	0.00	0 to 0

Table 5
Summary of Host Range Tests in Quarantine with *Bagous hydrillae* (See Following Tables for Data)

Family–Genus and Species	Total Insects	No.[1] Tests	Test Duration days	Adult[2] Feeding	Oviposition[3]	Adults[4] Produced
Monocotyledons						
Alismataceae						
Sagittaria subulata (L.)Buchenau	18	1	7	+	0	0
Sagittaria kurziana Glueck	18	1	7	+	0	0
Araceae						
Pistia stratiotes L.	180	2	1-3	+	0	0
Colocasia esculenta (L.)Schrad.	36	1	7	0	--	--

(Sheet 1 of 4)

[1] Choice and no-choice tests.
[2] Range of test means; (+) = 0.01 - 0.50 mm^3/insect/day; (++) = 0.51 - 1.00 mm^3; (+++) = 1.01 - 2.00 mm^3; (++++) = 2.01 - 4.64 mm^3; 93 percent of the hydrilla tests produced feeding greater than 1.0 mm^3.
[3] $\left(\frac{\text{Mean Eggs on Test Plant}}{\text{Mean Eggs on Hydrilla}}\right)$ x 100; Range of test percents. (+) = 33 percent or less; (++) = 34 to 66 percent; (+++) = 67 to 100 percent; (++++) >100 percent; ? = adults emerged from eggs that were overlooked during examination of the plant.
[4] $\left(\frac{\text{Mean adults emerged on test plant}}{\text{Mean adults produced on hydrilla}}\right)$ x 100; Range of test percents. (+) = 33 percent or less; (++) = 34 to 66 percent; (+++) = 67 to 100 percent; (++++) >100 percent.

Table 5 (Continued)

Family--Genus and Species	Total Insects	No. Tests	Test Duration days	Adult Feeding	Oviposition	Adults Produced
Commelinaceae						
Zebrina pendula Schnizl.	312	2	3	+	0	0
Tradescantia sp.	156	1	3	0	0	0
Commelina sp.	156	1	3	+	0	--
Hydrocharitaceae						
Limnobium spongia (Bosc)Steud.	102	4	7	+/++++	0-?	0/+
Egeria densa Planch.	36	2	7	++	+/++	+/+++
Elodea canadensis L.C.Rich	84	4	7	+++/++++	+/+++	+/++
Hydrilla verticillata (L.f.)Royle	1,993	44	1-7	++/++++	+++	+++
Vallisneria americana Michx.	246	5	1-7	+/++++	0/++++	++/++++
Najadaceae						
Najas guadalupensis (Spreng.)Magnus	234	5	1-7	++/++++	0/++	0/++++
Poaceae						
Oryza sativa L.	218	4	1-7	0/+	0	0
Potamogetonaceae						
Potamogeton perfoliatus L.	36	2	7	+/++	?	0/+
Potamogeton illinoensis Morong	234	5	1-7	+/++	0	0
Potamogeton crispus L.	216	4	1-7	+/++++	0/+	0

Table 5 (Continued)

Family--Genus and Species	Total Insects	No. Tests	Test Duration days	Adult Feeding	Oviposition	Adults Produced
Dicotyledons						
Aizoaceae						
Sesuvium portulacastrum (L.)L.	336	3	1-4	+/++	0	0
Asteraceae						
Lactuca sativa L.	270	4	3-7	0/+	0	0
Brassicaceae						
Brassica oleracea var. *acephala* DC.	24	1	7	+	--	--
Brassica juncea (L.) Czernj & Cosson var. *juncea*	36	1	7	+	--	--
Brassica oleracea var *capitata* L.	36	1	7	0	--	--
Nasturtium officinale R. Br.	18	1	7	+	0	0
Raphanus sativus L.	270	4	3-7	0/+	0	0
Brassica oleracea var. *botrytis* L.	36	1	7	0	--	--
Brassica rapa L. Rapifera Group?	36	1	7	0	--	--
Cabombaceae						
Cabomba caroliniana A. Grey	18	1	7	+	0	0
Ceratophyllaceae						
Ceratophyllum demersum L.	36	2	7	+	?	+
Crassulaceae						
Crassula argentea Thumb.	312	2	3	0/+	0	0

Table 5 (Concluded)

Family–Genus and Species	Total Insects	No. Tests	Test Duration days	Adult Feeding	Oviposition	Adults Produced
Sedum sp.	312	2	3	+/++	0	0
Graptopetalum sp.	312	2	3	0	0	0
Cucurbitaceae						
Cucumis sativus L.	122	4	3-5	0/+	0	0
Cucurbita pepo L.	180	2	6-7	0	0	0
Citrullus lanatus (Thumb.)Matsum. & Nakai var. lanatus	198	2	6-7	0	0	0
Fabaceae						
Phaseolus vulgaris L.	12	1	6	0	0	0
Haloragaceae						
Myriophyllum aquaticum (Vell.)Verdc.	18	1	7	+	0	0
Menyanthaceae						
Nymphoides aquatica (S.G.Gmel.)Kuntze.	18	1	7	+	0	0
Rutaceae						
Citrus sp.	12	1	7	0	--	--

Table 6
Summary of No-choice Adult Feeding Tests with *Bagous hydrillae*

Test Plant	Test No.[1]	No. Insects/ Replicate	No. Replicates	No. Days	$\bar{x}$ mm³/insect/day[2]		$\bar{x}$ mm³/insect/day[3] % of Hyd control	
					Minimum	Maximum	Minimum	Maximum
Najas guadalupensis	BA-87-9	2	45	1	5.64	5.77	106	106
Potamogeton crispus	BA-87-9				3.41	3.53	64	65
Potamogeton illinoensis	BA-87-9				1.22	1.23	23	23
Hydrilla	BA-87-9				5.34	5.46	100	100
Najas guadalupensis	BA-87-9a	2	45	3	3.30	3.76	82	83
Potamogeton crispus	BA-87-9a				3.25	3.85	81	85
Potamogeton illinoensis	BA-87-9a				1.26	1.51	31	33
Hydrilla	BA-87-9a				4.02	4.52	100	100
Oryza sativa	BA-87-12	2	45	1	0.00	0.00	0	0
Vallisneria americana	BA-87-12				2.18	2.28	68	70
Hydrilla	BA-87-12				3.20	3.27	100	100

(Sheet 1 of 4)

[1] Plant material in Tests BA-87-9, BA-87-12, BA-87-15, and BA-88-12 was changed after 1 day as per Australian techniques. New material was added, and tests were terminated 3 days later. Plant material in all tests with six females per replicate were exposed in water.

[2] Minimum $\bar{x}$ was calculated with number of insects at start of test; maximum $\bar{x}$ was calculated with number alive at end of test. These were calculated because of differential mortality among eggs.

[3] $\left(\frac{\bar{x}\ \text{mm}^3\text{/insect/day on test plant}}{\bar{x}\ \text{mm}^3\text{/insect/day on simultaneous hydrilla control}}\right) \times 100$; calculated from minimum and maximum means.

Table 6 (Continued)

Test Plant	Test No.	No. Insects/ Replicate	No. Replicates	No. Days	$\bar{x}$ mm³/Insect/day		$\bar{x}$ mm³/Insect/day % of Hyd control	
					Minimum	Maximum	Minimum	Maximum
Oryza sativa	BA-87-12a	2	45	3	0.00	0.00	0	0
Vallisneria	BA-87-12a				1.13	1.51	39	38
Hydrilla	BA-87-12a				2.87	3.97	100	100
Sesuvium portulacastrum	BA-87-14	52	3	4	0.26	-	12	-
Hydrilla	BA-87-14				2.26	-	100	-
Sesuvium portulacastrum	BA-87-15	2	45	1	0.92	0.99	35	34
Hydrilla	BA-87-15				2.62	2.88	100	100
Sesuvium portulacastrum	BA-87-15a	2	45	3	0.18	0.28	7	8
Hydrilla	BA-87-15a				2.68	3.54	100	100
Cabomba caroliniana	BA-88-5	6	3	7	0.05	0.05	2	2
Myriophyllum aquaticum	BA-88-5				0.02	0.02	1	1
Vallisneria americana	BA-88-5				0.10	0.10	5	5
Hydrilla	BA-88-5				1.90	2.01	100	100
Limnobium spongia[4]	BA-88-7	6	3	7	4.36	15.68	132	343
Hydrilla	BA-88-7				3.31	4.58	100	100

[4] Feeding on *L. spongia* was mostly on the air-filled aerhynchyma tissue on the underside of leaves; this spongy flotation layer was removed before testing in BA-89-2.

Table 6 (Continued)

Test Plant	Test No.	No. Insects/ Replicate	No. Replicates	No. Days	$\bar{x}$ mm³/Insect/day		$\bar{x}$ mm³/Insect/day % of Hyd control	
					Minimum	Maximum	Minimum	Maximum
Potamogeton illinoensis	BA-88-9	6	3	7	0.12	0.21	5	7
Sagittaria subulata	BA-88-9				0.31	1.39	12	45
Hydrilla	BA-88-9				2.58	3.10	100	100
Potamogeton illinoensis	BA-88-11	6	3	7	0.13	0.21	7	11
Potamogeton perfoliatus	BA-88-11				0.53	1.06	28	56
Sagittaria kurziana	BA-88-11				0.25	0.37	13	20
Hydrilla	BA-88-11				1.89	1.89	100	100
Pistia stratiotes	BA-88-12	2	45	1	0.26	0.26	6	6
Hydrilla	BA-88-12				4.59	4.59	100	100
Pistia stratiotes	BA-88-12a	2	45	3	0.16	0.19	7	7
Hydrilla	BA-88-12a				2.39	2.59	100	100
Nasturtium officianale	BA-88-13	6	3	7	0.01	0.02	1	2
Hydrilla	BA-88-13				1.02	1.41	100	100
Oryza sativa	BA-88-15	6	3	7	0.00	0.00	0	0
Oryza sativa seedlings	BA-88-15				0.02	0.02	1	1
Hydrilla	BA-88-15				2.33	3.23	100	100
Limnobium spongia[4]	BA-88-16	6	3	7	3.10	3.72	130	130
Hydrilla	BA-88-16				2.39	2.86	100	100

Table 6 (Concluded)

Test Plant	Test No.	No. Insects/ Replicate	No. Replicates	No. Days	$\bar{x}$ mm³/Insect/day		$\bar{x}$ mm³/Insect/day % of Hyd control	
					Minimum	Maximum	Minimum	Maximum
Nymphoides aquatica	BA-88-22	6	3	7	0.48	0.97	25	34
Hydrilla	BA-88-22				1.90	2.85	100	100
Limnobium spongia [4]	BA-89-2	6	3	7	0.31	0.57	14	22
Hydrilla	BA-89-2				2.15	2.57	100	100

Table 7
Summary of Multichoice Adult Feeding Tests with *Bagous hydrillae*

Test Plant[1]	Test No.	No. Insects/ Replicate	No.[2] Replicates	No. Days	Test Plant[1] $\bar{x}$ mm³/insect/day[3]		Paired Hydrilla $\bar{x}$ mm³/insect/day[4]	
					Minimum	Maximum	Minimum	Maximum
Citrullus lanatus	BA-87-16	162	1	7	0	--	--	
Cucurbita pepo	BA-87-16				0	--	--	
Lactuca sativa	BA-87-16				0.13	--	--	
Raphanus sativus	BA-87-16				0	--	--	
Cucumis sativus	BA-87-17	6	6	3	0	--	1.93	2.18
Lactuca sativa	BA-87-17				0.02	0.03	1.93	2.18
Cucumis sativus	BA-87-18	6	6	3	0	--	1.91	2.21
Raphanus sativus	BA-87-18				0	--	1.91	2.21
Lactuca sativa	BA-87-20	6	6	7	0	0	1.07	1.60
Raphanus sativus	BA-87-20			7	0.04	0.12	1.07	1.60
Brassica juncea	BA-87-21	6	6	7	0.01	0.02	--	
Brassica oleracea ace	BA-87-21		4		0.01	0.02	--	

(Continued)

[1] Test plants exposed together with or without hydrilla.
[2] In Test BA-87-21, two species were not included in every replicate.
[3] Minimum $\bar{x}$ was calculated with number of insects at start of test; maximum $\bar{x}$ was calculated with number alive at end of test. These were calculated because of differential mortality among cages.
[4] Five tests included hydrilla in the cages.

Table 7 (Concluded)

Test Plant	Test No.	No. Insects/ Replicate	No. Replicates	No. Days	Test Plant $\bar{x}$ mm³/insect/day		Paired Hydrilla $\bar{x}$ mm³/insect/day	
					Minimum	Maximum	Minimum	Maximum
Brassica oleracea bot	BA-87-21		6		0	0	--	
Brassica oleracea cap	BA-87-21		6		0	0	--	
Brassica rapa	BA-87-21		6		0	0	--	
Citrus sp.	BA-87-21		2		0	0	--	
Crassula argentea	BA-88-6	52	3	3	0.05	0.05	--	
Graptopetalum sp.	BA-88-6				0.10	0.11	--	
Sedum sp.	BA-88-6				0.71	0.75	--	
Tradescantia sp.	BA-88-6				0	0.00	--	
Zebrina pendula	BA-88-6				0.01	0.01	--	
and								
Hydrilla Alone[5]	BA-88-6	52	3	3	3.31	3.52	--	
Commelina sp.	BA-88-10	52	3	3	0.01	0.01	2.04	2.08
Sedum sp.	BA-88-10				0.03	0.03	2.04	2.08
Zebrina pendula	BA-88-10				0.01	0.01	2.04	2.08
Crassula argentea	BA-88-14	52	3	3	0	0	1.63	1.64
Graptopetalum sp.	BA-88-14				0	0	1.63	1.64

[5] Three replicates of hydrilla were set up as a simultaneous control in BA-88-6.

Table 8
Summary of Paired-Choice with Host Adult Feeding Tests with *Bagous hydrillae*

List Plant[1]	Test No.	Test Plant $\bar{x}$ mm³/insect/day[2]		Paired Hydrilla $\bar{x}$ mm³/insect/day		Hydrilla Alone $\bar{x}$ mm³/insect/day		Test $\bar{x}$ mm³/insect/day[3] % of Paired Hydrilla $\bar{x}$	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Egeria densa	BA-88-2	0.53a	0.96a	1.05a	1.98a	2.26	3.40	50	48
Vallisneria americana	BA-88-2	0.05a	0.06a	1.80b	1.96b			3	3
Elodea canadensis	BA-88-3	1.80a	2.73a	1.18a	2.11a	2.28	2.91	153	129
Egeria densa	BA-88-7	0.90a	1.85a	1.57a	2.91a	3.31	5.41	57	64
Ceratophyllum demersum	BA-88-7	0.06a	0.09a	1.57b	2.82b			4	3
Najas guadalupensis	BA-88-7	0.99a	2.12a	2.32a	4.22b			43	50
Potamogeton crispus	BA-88-7	0.21a	0.62a	1.32b	3.43b			16	18
Najas guadalupensis	BA-88-9	0.51a	0.86a	1.67a	2.74a	2.58	3.10	31	31
Potamogeton illinoensis	BA-88-15	0.20a	0.21a	0.79b	0.84a	2.33	3.23	25	25
Potamogeton perfoliatus	BA-88-15	0.36a	0.50a	0.73a	1.01a			49	50
Elodea canadensis	BA-88-17	1.31a	2.37a	0.91a	1.64a	1.73	2.40	144	145
Limnobium spongia	BA-88-21	0.35a	0.52a	1.18b	1.77a	2.02	3.03	30	29

[1] Each test plant was paired with hydrilla in a 3.8-ℓ glass jar containing water. Three replicates of each test plant-hydrilla pair; six females per replicate; duration 7 days. Three replicates of hydrilla alone were set up as a simultaneous control.

[2] Minimum $\bar{x}$ was calculated with number of insects at start of test; maximum $\bar{x}$ was calculated with number alive at end of test. Means within comparable columns within a row followed by the same letter were not significantly different. Paired t-test ($p = 0.05$). Data was transformed before analysis with $\sqrt{x+.05}$ because of unequal variances due to zeroes and small values. Feeding on the aerhynchyma tissue of *L. spongia*, BA-88-21, was not included.

[3] $\left(\frac{\bar{x} \text{ on test plant}}{\bar{x} \text{ on paired hydrilla}}\right) \times 100$

Table 9
Summary of No-Choice Oviposition and Larval Development Tests with *Bagous hydrillae*

Test Plant	Test No.[1]	No. Females/ Replicate	No. of [2] Replicates	No. Days	Total Eggs	$\bar{x}$ Eggs/Female/Day		$\bar{x}$ Eggs/Female/Day % of Hydrilla Control		Total[3] Adults Produced	Adults %
						Min.	Max.	Min.	Max.		
Potamogeton illinoensis	BA-87-9	1	45	1	0	0	0	0	0	--	--
Potamogeton crispus	BA-87-9				0	0	0	0	0	--	--
Najas guadalupensis	BA-87-9				0	0	0	0	0	--	--
Hydrilla	BA-87-9				11	0.24	0.26	100	100	--	--
Potamogeton illinoensis	BA-87-9a	1	44	3	0	0	0	0	0	--	--
Potamogeton crispus	BA-87-9a		43		0	0	0	0	0	--	--
Najas guadalupensis	BA-87-9a		44		46	0.35	0.39	21	21	--	--
Hydrilla	BA-87-9a		43		117	0.93	0.98	0	0	--	--
Vallisneria americana	BA-87-12	1	45	1	0	0	0	0	0	--	--
Oryza sativa	BA-87-12				0	0	0	0	0	--	--
Hydrilla	BA-87-12				0	0	0	0	0	--	--
Vallisneria americana	BA-87-12a	1	45	3	2	0.04	0.04	67	65	--	--
Oryza sativa	BA-87-12a		43		0	0	0	0	0	--	--
Hydrilla	BA-87-12a		43		3	0.02	0.03	100	100	--	--

[1] These were also feeding tests. See footnotes on Table 5 for details.
[2] Number of replicates of 3-day tests varied because of mortality during the 1-day tests that preceded them.
[3] Plant material from the 1- and 3-day tests was not held for larval development; plant material from the 7-day tests was removed from water after 7 days, examined for eggs, and held on moist sand for larval development.

Table 9 (Continued)

Test Plant	Test No.	No. Females/ Replicate	No. of Replicates	No. Days	Total Eggs	$\bar{x}$ Eggs/Female/Day		$\bar{x}$ Eggs/Female/Day % of Hydrilla Control		Total Adults Produced	Adults %
						Min.	Max.	Min.	Max.		
Sesuvium portulacastrum	BA-87-15	1	45	1	0	0	0	0	0	--	--
Hydrilla	BA-87-15				3	0.07	0.07	100	100	--	--
Sesuvium portulacastrum	BA-87-15a	1	42	3	0	0	0	0	0	--	--
Hydrilla	BA-87-15a		42		19	0.15	0.18	100	100	--	--
Ceratophyllum demersum	BA-88-4	6	3	7	0	0	0	0	0	1	0
Najas guadalupensis	BA-88-4				53	0.42	0.50	57	45	0	0
Potamogeton crispus	BA-88-4				18	0.14	0.15	19	14	0	0
Hydrilla	BA-88-4				93	0.74	1.11	100	100	12	13
Cabomba caroliniana	BA-88-5	6	3	7	0	0	0	0	0	0	0
Myriophyllum aquaticum	BA-88-5				0	0	0	0	0	0	0
Vallisneria americana	BA-88-5				51	0.40	0.40	55	52	60	100+
Hydrilla	BA-88-5				93	0.74	0.78	100	100	60	65
Limnobium spongium	BA-88-7	6	3	7	0	0	0	0	0	0	0
Hydrilla	BA-88-7				56	0.44	0.62	100	100	11	20
Potamogeton illinoensis	BA-88-9	6	3	7	0	0	0	0	0	0	0
Sagittaria subulata	BA-88-9				0	0	0	0	0	0	0
Hydrilla only	BA-88-9				136	1.08	1.30	100	100	59	43

Table 9 (Concluded)

Test Plant	Test No.	No. Females/ Replicate	No. of Replicates	No. Days	Total Eggs	$\bar{x}$ Eggs/Female/Day		$\bar{x}$ Eggs/Female/Day % of Hydrilla Control		Total Adults Produced	Adults %
						Min.	Max.	Min.	Max.		
Potamogeton illinoensis	BA-88-11	6	3	7	0	0	0	0	0	0	0
Potamogeton perfoliatus	BA-88-11				0	0	0	0	0	0	0
Sagittaria kurziana	BA-88-11				0	0	0	0	0	0	0
Hydrilla	BA-88-11				135	1.07	1.07	100	100	12	9
Pistia stratiotes	BA-88-12	1	45	1	0	0	0	0	0	--	--
Hydrilla	BA-88-12				13	0.29	0.29	100	100	--	--
Pistia stratiotes	BA-88-12a	1	44	3	0	0	0	0	0	--	--
Hydrilla	BA-88-12a		45		179	1.33	1.44	100	100	--	--
Nasturtium officinale	BA-88-13	6	3	7	0	0	0	0	0	0	0
Hydrilla	GA 88-13				180	1.43	1.98	100	100	83	46
Oryza sativa seedlings	BA-88-15	6	3	7	0	0	0	0	0	0	0
Oryza sativa	BA-88-15				0	0	0	0	0	0	0
Hydrilla only	BA-88-15				175	1.39	1.92	100	100	20	11
Limnobium spongia	BA-88-16	6	3	7	6	0.05	0.06	0.01	0.01	6	?
Hydrilla	BA-88-16				468	3.71	4.46	100	100	23	5
Nymphoides aquatica	BA-88-22	6	3	7	0	0	0	0	0	0	0
Hydrilla	BA-88-22				302	2.40	3.60	100	100	26	9

Table 10
Summary of Paired-Choice Oviposition and Larval Development Tests with *Bagous hydrillae*

Test Plant[1]	Test No.	Test Plant				Paired Hydrilla				Hydrilla Alone			
		$\bar{x}$ Eggs[2]/ Female/Day (SD)		Total[3] Adults Produced	%[4] Adults	$\bar{x}$ Eggs/ Female/Day (SD)		Total Adults Produced	% Adults	$\bar{x}$ Eggs/ Female/Day (SD)		Total Adults Produced	% Adults
		Min.	Max.			Min.	Max.			Min.	Max.		
Egeria densa	BA-88-2	0.4a	0.8a	30	53	0.9a	1.8a	35	30	3.7	1.5	108	23
Vallisneria americana	BA-88-2	0.7a	0.7a	33	36	2.1a	2.2a	50	19				
Elodea canadensis	BA-88-3	0.7a	1.3a	4	5	0.8a	1.3a	53	51	1.5	0.7	76	41
Egeria densa	BA-88-7	0[5]a	0.1a	1	20	0.4a	0.9a	5	10	0.4	0.4	11	20
Ceratophyllum demersum	BA-88-7	0a	0a	1	?	0.3a	0.5a	5	16				
Najas guadalupensis	BA-88-7	0.1a	0.1a	9	100+	0.5a	1.2a	8	14				
Potamogeton crispus	BA-88-7	0[5]a	0a	0	0	0.2a	0.7a	11	37				
Najas guadalupensis	BA-88-9	0.2a	0.4a	1	4	1.6b	2.7a	35	18	1.1	1.2	59	43

(Continued)

[1] Each test plant was paired with hydrilla in a 3.8-ℓ glass jar containing water. Three replicates, six females per replicate, duration 7 days. All females had fed on hydrilla, and most were 1 to 2 weeks old. Hydrilla Alone = 3 cages of hydrilla set up as a simultaneous control for each test.
[2] After 7 days, feeding was estimated (see Table 8); eggs were counted in situ in the plant tissues; infested plants were held for larval development. Minimum $\bar{x}$ was calculated with number of females at start of test; maximum $\bar{x}$ with numbers alive at end.
[3] Plant material from the three replicates was held together for larval development.
[4] $\left(\frac{\text{Total Adults Produced}}{\text{Total Eggs}}\right)$ x 100: 100+ indicates that adults exceeded eggs, eggs were missed during counting; plant material could not be completely torn apart during examination because it was held for larval development. Eggs/female/day was adjusted to include the extra adults.
[5] Means round off to 0, but a few eggs were deposited.

Table 10 (Concluded)

Test Plant	Test No.	Test Plant				Paired Hydrilla				Hydrilla Alone			
		$\bar{x}$ Eggs/ Female/Day (SD)		Total Adults Produced	% Adults	$\bar{x}$ Eggs/ Female/Day (SD)		Total Adults Produced	% Adults	$\bar{x}$ Eggs/ Female/Day (SD)		Total Adults Produced	% Adults
		Min.	Max.			Min.	Max.			Min.	Max.		
Potamogeton illinoensis	BA-88-15	0a	0a	0	0	0.5a	0.5a	15	24	1.4	2.4	20	11
Potamogeton perfoliatus	BA-88-15	0a	0a	1	?	0.2a	0.3a	5	19				
Elodea canadensis	BA-88-17	0.1a	0.3a	20	100+	0.6a	1.2a	23	29	1.3	1.6	35	21
Limnobium spongia	BA-88-21	0a	0a	0	0	0.2a	0.3a	1	4	1.6	2.4	29	14

Appendix A
Quarantine Hydrilla Test Plant List

Taxonomic position of hydrilla (Takhtajan 1980):

Division	Spermophyta
Subdivision (Division Takhtajan)	Angiospermae
Class	Monocotyledonae
Subclass	Alismatidae
Order	Alismatales
Suborder	None
Family	Hydrocharitaceae
Subfamily	None
Tribe	None
Genus	*Hydrilla*
Species	*verticillata* L.

In same genus:
None, monotypic genus

In same family:

Egeria densa Planch.	introduced S.A. weed
Elodea canadensis Michx.	native
Limnobium spongia (Bosc) Steud.	native
Vallisneria americana Michx.	native

In same order:

Sagittaria kurziana Gluck	native
Sagittaria subulata (L.) Buchen.	native

In same subclass:

Najas guadalupensis (Spreng.)Magnus	native
Potamogeton crispus L.	introduced Eurasian weed
Potamogeton illinoensis Morong	native
Potamogeton perfoliatus L.	native

In same class:

Colocasia esculenta (L.)Schrad.	cultivated taro
Commelina sp.	introduced, ornamental
Oryza sativa L.	cultivated rice
Pistia stratiotes L.	introduced S.A. or Asian weed
Tradescantia sp.	introduced, ornamental
Zebrina pendula Schnizl.	introduced, ornamental

In same subdivision:

Brassica juncea (L.) Czernj & Cosson var. juncea	cultivated mustard
Brassica oleracea var. capitata L.	cultivated cabbage
Brassica oleracea var. acephala DC.	cultivated brussels sprouts
Brassica oleracea var. botrytis L.	cultivated broccoli
Brassica rapa L. Rapifera Group?	cultivated turnips
Cabomba caroliniana A. Grey	native
Ceratophyllum demersum L.	native
Citrullus lanatus (Thunb.) Matsum. & Nakai var. lanatus	cultivated watermelon
Citrus sp.	cultivated citrus
Crassula argentea Thunb.	introduced, ornamental
Cucumis sativus L.	cultivated cucumber
Cucurbita pepo L.	cultivated zucchini
Graptopetalum sp.	introduced, ornamental
Lactuca sativa L.	cultivated lettuce
Myriophyllum aquaticum (Vell.)Verdc.	introduced S.A. weed
Nasturtium officinale R. Br.	cultivated water cress, introduced weed
Nymphoides aquatica (S.G.Gmel.)Kuntze.	native
Phaseolus vulgaris L.	cultivated beans
Raphanus sativus L.	cultivated radish
Sedum sp.	introduced, ornamental
Sesuvium portulacastrum (L.)L.	native

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Biological studies and initial host range tests of *Bagous hydrillae* were conducted in Australia, and additional host range studies were conducted in the U.S. Department of Agriculture Quarantine Facilities at Gainesville, Florida. Both studies confirm the impact that *B. hydrillae* has on *Hydrilla verticillata*.

Bagous hydrillae attacks hydrilla stems. Adults feed externally and larvae mine internally. Damaged stems break away and float to shore where larvae mature and pupate. Heavy adult feeding produces a "mowing effect" on the hydrilla mat.

Extensive field sampling of aquatic plants from 1985-1988 proved that hydrilla was the primary host plant, although several additional submersed species were larval hosts during periods when hydrilla was scarce. It is doubtful if many larvae matured in these plant species, however, because little plant material was found along with hydrilla stranded on shore where the larvae pupate. It is believed that *B. hydrillae* has the potential to greatly increase the stress on hydrilla in southern states where hydrilla is most abundant.

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